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by Indah Siradjuddin

Region Based Segmentation Using Morphological Mathematics And Laplacian Of Gaussian To Automatically Detect Retinal Blood Vessel Image

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Abstract

In this research, we propose a retinal blood vessel segmentation method with a new approach, namely region based segmentation using morphological mathematics and the Laplacian of Gaussian. The process begins with improved image segmentation using CLAHE, followed by the process of transformation into a binary image. The next process is to remove the vascular ring. Binary image result is improved to process the image morphology. The last process is to remove the border and noise that appear due to the results of the previous process. We have performed five experimental scenarios by using retinal DRIVE image database. The experimental results show an increase in accuracy from the first to the last experiment. The average accuracy of our experimental results is 90.15%.

Keywords: *Morphology, Laplacian, Gaussian, Blood Vessel, Retinal Image, Segmentation.*

1. Introduction

Recently, the disease diabetic retinopathy is a disease common in humans at a young age. This is in contrast to 20 years ago; the disease tends to attack people whose age is above 50 years. The shift pattern and lifestyle lead to a shift in trend of the diabetic retinopathy disease at a young age.

The emergence of many diseases that occur in people at a young age, it is necessary to early detection of disease so that treatment is not delayed. Diseases such as diabetes have decreased its tendency arise in the offspring. A person suffering from diabetes can be detected through lesion attached to the eye. In order to find existing lesion the fundus image, required several steps, namely blood vessels segmentation, optic disc segmentation and removal of their results [1-7]. The result of the elimination of retinal blood vessels and optic disc will leave lesion [1][8-11]. Lesion remaining objects can be classified to determine the type of diabetes that affects a person. It is necessary to perform blood vessel segmentation and optic disc detection to obtain the lesion of the retinal image. In this research, we also research the blood vessel segmentation.

Crucial problem on the retinal image segmentation process is a small difference between the blood vessels, optic nerve head, lesion, and background image input [10][12-17]. Small differences between objects in the retinal images will lead to failure on the blood vessel segmentation [2][5][18-26]. In this research, we proposed segmentation method, which is a region based segmentation using morphological mathematics and Laplacian of Gaussian.

We will explain the remainder of our paper into eight sections. Our proposed method will be explained on the 2nd section. The 3rd until 7th Sections will describe detailed of a proposed method, which are image enhancement, binary image transformation, removing of retinal ring, image morphology process, and removing noise, image border from the previous stage. Accuracy Measurement will be explained on the 8th section. Experimental results and analysis will be described on the 9th section. And the last section contains the conclusion of the research

2. Proposed Method

To achieve the segmentation maximal accuracy, we proposed method a new segmentation model. In this proposed method, we have divided five main stages, which are image enhancement, image transformation to binary, removing fundus ring, morphological image, and removing noise and image border from the previous stage as shown in Figure 1. The first stage is image enhancement, process to enhance image quality. In this research, we utilize *Contrast Limited Adaptive Histogram Equalization* to enhance it. The second stage, the results of image enhancement will be transformed to a binary image. Its problem is how to determine the best threshold. We proposed Otsu's method to obtain the best threshold. The third stage is removing the retinal image ring from the binary image. We proposed overlapping mask model to remove the retinal image ring. The fourth stage is conducting image morphology; we use dilation to thicken retinal blood vessel image. The last stage, noises and remaining rings will be cleaned using field of view method.

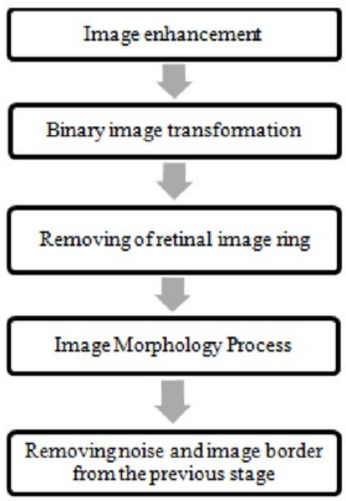

Figure 1. Framework of Proposed Method

3. Image Enhancement Based On Contrast Limited Adaptive Histogram Equalization (Clahe)

Image enhancement plays an important role to segment retinal blood vessel. The lower quality of the processed image, the lower accuracy of the resulting image segmentation, and vice versa, the better image is processed, the higher accuracy obtained [12]. In this research, we proposed *Contrast Limited Adaptive Histogram Equalization* method as well known as CLAHE. In this stage, the green channel retinal color image is used as input. Suppose the gray level image is represented by using x, L represents gray level range, and n_i is the number of frequencies of each gray level, and then the i-th *occurrence probability* and *cumulative distribution function* can be written using equation

$$p_x(i) = p(x = i) = \frac{n_i}{n}, \quad 0 \le i \le L \tag{1}$$

$$cdf_x(i) = \sum_{j=0}^{i} p_x(j) \tag{2}$$

If $y = T(x)$ is transformed into a new image {y}, then image *cumulative distribution function* can be expressed by using equation

$$cdf_y(i) = iK \tag{3}$$

The $y=f(x)$ transformation changes the pixels distribution, but the number of pixels is unchanged as shown on the following equation

$$p(y)dy = p(x)dx \tag{4}$$

Image enhancement using CLAHE can be shown in Figure 2

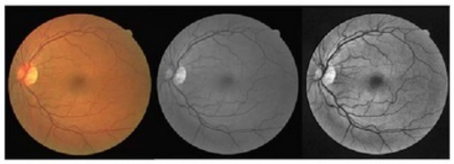

Figure 2. Retinal color image (The 1st image of DRIVE image database), Green Channel image and image enhancement using CLAHE method.

4. Binary Image Transformation

The second stage of our proposed method is image transformation to binary. In this stage, the result of image enhancement is used as image input. In order to transform to binary image we proposed five stages to conduct it as shown in Figure 3. They are building *Laplace of Gaussian* matrix, image convolution using *Laplace of Gaussian* matrix, determination threshold using the Otsu's method, binary image transformation based on the Otsu threshold result, and removing noise from previous result.

First, it is necessary to obtain mask matrix, we proposed *Laplacian* to build mask matrix. *Laplacian* can be used to detect image edge with a significant change, which is the second derivative as shown in the following equation

$$\frac{\partial^2}{\partial x^2} G(x,y) = \left(\frac{x^2 - \sigma^2}{\sigma^4}\right) e^{-\frac{x^2+y^2}{2\sigma^2}} \tag{5}$$

$$\frac{\partial^2}{\partial y^2} G(x,y) = \left(\frac{y^2 - \sigma^2}{\sigma^4}\right) e^{-\frac{x^2+y^2}{2\sigma^2}} \tag{6}$$

$$\nabla^2 G(x,y) = \frac{\partial^2}{\partial x^2} G(x,y) + \frac{\partial^2}{\partial y^2} G(x,y) \tag{7}$$

$$\nabla^2 G(x,y) = \frac{1}{\sigma^2}\left(\frac{x^2 + y^2}{\sigma^2} - 2\right) e^{-\frac{x^2+y^2}{2\sigma^2}} \tag{8}$$

If the *Gaussian* value is defined as $\frac{1}{\sqrt{2\pi\sigma^2}}$, then the value of *LoG* can be written by using the following equation

$$LoG = -\frac{1}{\sqrt{2\pi\sigma^2}}\left(\frac{1}{\sigma^2}\left(1-\frac{x^2+y^2}{2\sigma^2}\right)e^{-\frac{x^2+y^2}{2\sigma^2}}\right) \tag{9}$$

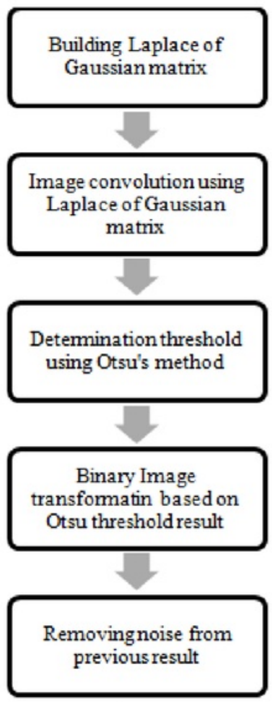

Figure 3. Binary Image Transformation

Secondly, image input is convoluted by using *LoG* mask matrix. The difference between background and retinal blood vessel can be clear shown after convolution process. Thirdly is determination the best threshold by using the Otsu's method. The Otsu's method can be started by determination *within* and *between class variance* values as shown in the following equation

$$\sigma_w^2 = W_b^2\sigma_b^2 + W_f^2\sigma_f^2 \tag{10}$$

$$\sigma_B^2 = \sigma^2 - \sigma_W^2$$
$$\sigma_B^2 = W_b(\mu_b - \mu)^2 + W_f(\mu_f - \mu)^2 \tag{11}$$

The fourthly is binary image transformation; it is conducted by using Otsu's *threshold* as shown on the following equation

$$I_{Binnery} = \begin{cases} 0 & if \quad f(x,y) \leq threshold \\ 1 & if \quad f(x,y) > threshold \end{cases} \quad (12)$$

Lastly, the result of Equation (12) consists of many noises, it is necessary to remove noise as shown in Algorithm 1. It is conducted to obtain the better results.

```
∀Num, Num∈1. .NumOfObject
  If Area of Object(Num)<Threshold
    Replace Gray Scale of Object(Num) ←0
  end
end
```

Algorithm 1. Removing Noise Algorithm

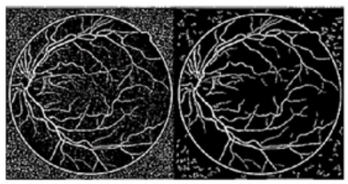

Figure 4. Binary Image Transformation and Removing Noise from the 1st of DRIVE Database

5. Removing Of Retinal Image Ring

The process of throwing the object border of the fundus also means remove noise that are outside of the fundus. Binary image result from a previous process will be used as input. To remove retinal image ring, it is necessary to build image masking as shown in Figure 6. To build image masking, we used red image channel as input. Image masking can be built by determination the best threshold using entropy [21] and followed by binary image transformation. The result of image masking is summed with binary image as the result of Equation (12) as shown in Figure 7. The next result is negated as shown in Figure 5

Entropy threshold can be determined by computing the upper and the lower entropy as shown on the following equation

$$Entr_{Upper} = -\frac{1}{2}\sum_{i=1}^{RowU}\sum_{j=1}^{ColU} M_{i,j} * U \quad (13)$$

$$Entr_{Lower} = -\frac{1}{2}\sum_{i=1}^{RowL}\sum_{j=1}^{ColL} M_{i,j} * L \quad (14)$$

$$U = \log 2\left(\sum_{i=1}^{RowL}\sum_{j=1}^{ColL} M_{i,j} + C\right) \quad (15)$$

$$L = \log 2\left(\sum_{i=1}^{RowL}\sum_{j=1}^{ColL} M_{i,j} + C\right) \quad (16)$$

$$Entr_{Total} = Entr_{Upper} + Entr_{Lower} \quad (17)$$

The best threshold value is determined by comparing the results of each iteration entropy process. The produced best threshold is an index or value entropy iteration of the value generated [21].

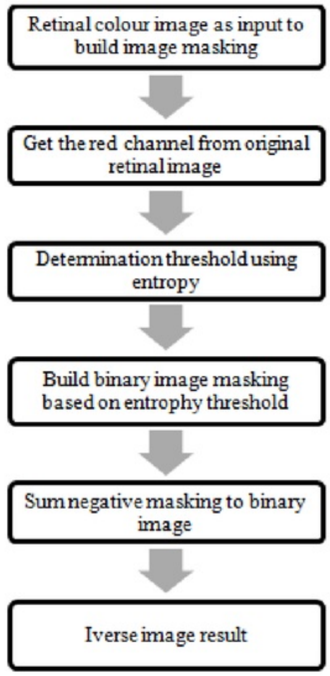

Figure 5. Removing of Retinal Image Ring.

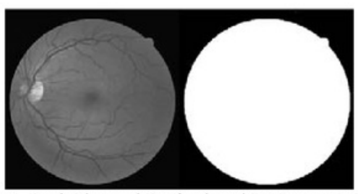

Figure 6. Red Channel Retinal and Its Image Masking

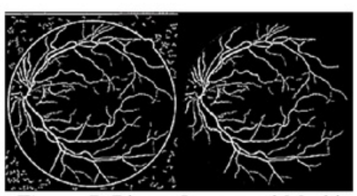

Figure 7. Binary Image and Masking

6. Image Morphology Process

The results of blood vessel segmentation as shown in Figure 7 are thin. It is necessary to dilate the image to obtain the best accuracy result, i. Image dilation is a way to thicken an object in an image [18]. Morphological play the important rule to produces the best blood vessel segmentation. Thinning and thicken will give big influences to the final result segmentation. Opening and closing process will also influence the last results.

The result of image dilation depends on the structuring element used. Image dilation can be mathematically expressed.

$$X \oplus B = \{x \mid B_x^2 \subset X^c\} \tag{18}$$

The usage of structuring element is an important factor on the morphological process. The failure of structuring element determination will give bad effect to the last results [1][4][7].

7. Noise and Ring Removing From the Previous Stage.

Unfortunately, the image dilation caused rings image reappears. It is occurred because of thicken process by using the dilation method. In order to remove noise and ring, we proposed field of view to overcome it as shown in Figure 8. In this stage, we need image masking. It can be created by using binary process based on entropy threshold. Image convolution is performed by using high pass filtering and followed by determination of convolution. Lastly, the image result must be matched to obtain the best accuracy.

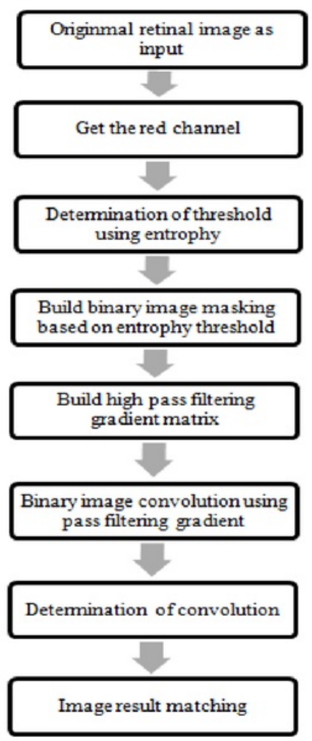

Figure 8. Field of View Process

8. Accuracy Measurement

In order to measure the reliability of experimental results, we used *sensitivity*, *specificity*, and *accuracy* as shown in the following equation. The ground truth images are used as a reference to obtain *sensitivity*, *specificity*, and *accuracy*. If the results of blood vessel segmentation pixels are detected correctly, then the value of *TP* (True Positive) increased 1, otherwise the value *FN* (False negative) increased 1. If the background segmentation pixels are correctly detected, then the value of *TN* (True Negative) increased 1, otherwise the value of *FP* increased 1.

$$Sensityvity = \frac{TP}{TP + FN} \tag{19}$$

$$Specificity = \frac{TN}{TN + FP} \tag{20}$$

$$Accuracy = \frac{TP + TN}{TP + FP + TN + FP} \tag{21}$$

9. Experimental Results and Analysis

In this research, we use DRIVE database images for experimental [27]. It consists of 20 original images, 20 ground truth images. Image sample of retinal DRIVE image database can be shown in Figure 9. Segmentation results of our proposed method are also compared with ground truth image by using Equation (19), (20) and (21). We have conducted five experimental scenarios to test the reliability of our proposed method as shown in Table 1.

Table 1. Experimental Scenario of Proposed Method

Proposed Method Scenarios	Parameters Used
1st	X=5, σ=1.8, *se*=3 T1=35 without noise removal after field of view process
2nd	X=5, σ=1.8, *se*=3 T1=35 and T2=240 without image mask overlapping
3rd	X=5, σ=1.8, *se*=3 T1=35 and T2=240 with image mask overlapping
4th	X=3, σ=1.2, *se*=3 T1=35 and T2=240 without image mask overlapping
5th	X=3, σ=1.2, *se*=3 T1=35 and T2=240 with image mask overlapping

The usage of an image mask overlapping, the value of X and deviation standard influences the accuracy. Experimental results show an increase in accuracy from the first to the last experiment. It means that, the last experimental results showed that the accuracy obtained is higher than the four previous experiments as seen in Figure 12. The average of the 5th experimental results using the DRIVE database images is 90 15%. On the last experiment, the second image produces the highest accuracy, which is 92.52% as shown in Figure 10.

Figure 9. The 1st Original and Ground Truth DRIVE Image Database

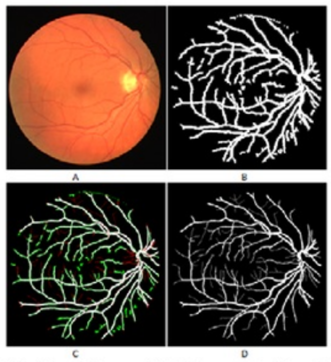

Figure 10. (A). Original Image,(B). Segmentation Result,
©. Tagging Results and (D). Ground Truth of the 2nd the DRIVE Image Database.

The Lowest accuracy occurred on the 9th image. Fault of detection is caused by the ends of the blood vessels that are not detected when the segmentation process. This is due, to a loss of fine blood vessels when the object is disconnected from the tip of its parent. The same fault of detection also occurred on the 3rd, 6th, 9th, 13th, 17th, and 20th. Detection failures are caused by the transformation process into a binary image, in the case the end of the gray level value of blood vessels are smaller than the threshold, so that the ends of blood vessels is changed into the background image of the fundus.

Our experimental results have been compared to other methods, which are Chaudhuri et al. [25] and Jiang et al. [26]. Table 1 shows that, the 1st experimental result is not better than Chaudhuri et al. [25], however the 2nd until the last experiments have higher accuracy than Chaudhuri et al. [25]. The experimental of Jiang et al [26] produces higher accuracy then the 1st until the 3rd of our experimental results. However, it is not higher than the 4th and 5th of our experimental results.

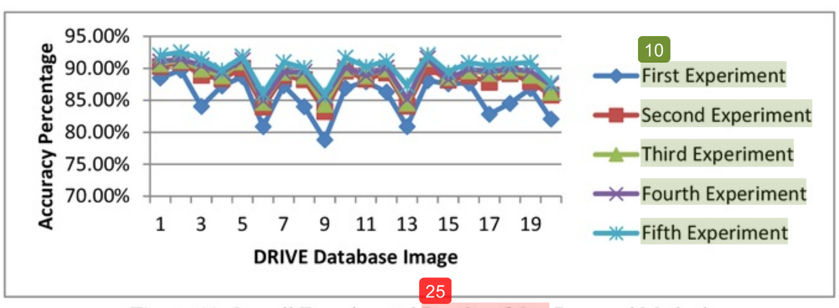

Figure 11. Overall Experimental Results of Our Proposed Method

Table 2. Comparison of the accuracy of the segmentation results

Method	Accuracy (%)
Chaudhuri et al. [20]	87.77
Jiang et al. [21]	89.11
Our Proposed Method	
The 1st Scenario	85.54
The 2nd Scenario	88.11
The 3rd Scenario	88.80
The 4th Scenario	89.16
The 5th Scenario	90.15

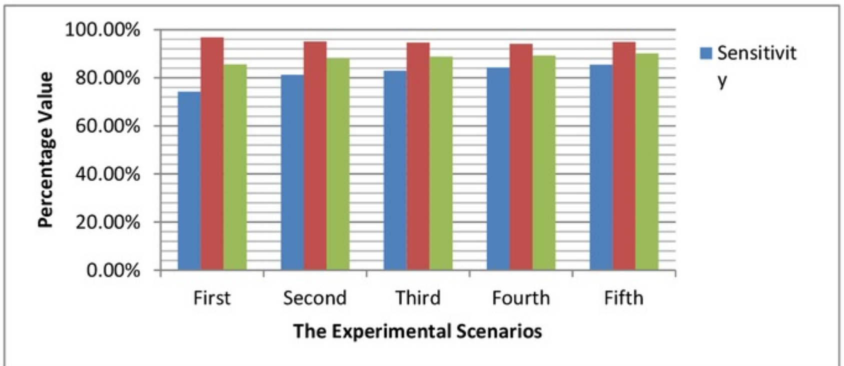

Figure 12. The average of Sensitivity, Specificity and Accuracy Obtained of Our Proposed Method

10. Conclusions

In this research, the usage of image mask overlapping and parameters used influence the accuracy. Experimental results show that the average higher accuracy of our proposed method is 90.15%. We can conclude that segmentation failures that occurred on subtle branches of the retinal blood vessels are caused by interruption between blood vessels ends and the main branch. Delicate branches severed regarded as noise, so that the branches be lost when the noise removal process. If the noise removal process is not done, then a lot of noises transformed into a binary image that remains until the end of the segmentation process is done. It means that the noise removal process is not conducted. It will increase the value of specificity but decreases the value of specificity. They produced the lower accuracy than other images.

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